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Sales Location and Supply Response among Semisubsistence Farmers in Benin

A Heteroskedastic Double Selection Model

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ABSTRACT

In much of rural Africa, high transaction costs limit farmers' market participation and thus their potential for income growth. Transaction costs can affect not only whether a farmer sells product but also whether sales occur at the farm gate on at a market. If production behavior is related to a chosen sales location, then analysis of interventions can be improved by explicit consideration of the decision of where to sell. This paper develops a double-selection model that explains consumption and production decisions by semi-subsistence farmers who first decide whether to be a seller and then whether to sell at the farm gate or at an off-farm location before deciding on production and consumption. The study tests the validity of this dual-criteria model against a single criterion model in which a grower first decides to be a seller and then decides production, consumption and sales location simultaneously. Dual-criteria and single-criterion models are compared while correcting inconsistency in estimations due to violation of homoskedasticity and normality assumptions in selection equations. The results suggest that the dual-criteria model provides more information than the single-criterion model using a sample of cassava producer in Benin.

Keywords: dual-criteria, transaction costs, sales location, agricultural supply response, Benin

1. INTRODUCTION

High transaction costs faced by semisubsistence farmers may often preclude market participation and exclude them from the benefits of commercial production. Based largely on transaction costs, farmers self-select to produce for sale or purely for home consumption. Producers' response to price changes and new technologies will vary systematically with market orientation if production decisions are made after the decision of whether or not to market the product. Though it is less frequently acknowledged, a farmer may make production decisions with an intent not to incur the costs associated with travel to market but still to sell surplus from the farmgate. This suggests that response to technology and price changes may vary systematically across farmers who have self-selected to sell off-farm, to sell at the farmgate, or not to sell at all. Recognition of these three categories of producers could contribute to improved understanding of supply response and better targeting of interventions, especially in Africa, where transaction costs are often high and semisubsistence production is common.

While many studies have examined the effect of high transaction costs on farmers' production strategies (Goetz 1992; Renkow, Hallstrom, and Karanja 2004), the transaction costs associated with choice of market outlet have only recently gained attention. Fafchamps and Hill (2005) raised the possibility that transaction costs are associated with sellers' self-selection to sell from the farmgate or from an off-farm location. The main interest of this paper is whether fixed transaction costs are high enough that cassava producers in West Africa choose whether to sell cassava at the farmgate or elsewhere before deciding input levels for cassava production.[1] Cassava farmers are an appropriate group for analyzing the effect of such sales location decisions on production and consumption decisions for two reasons. First, transportation costs are relevant for crops like cassava, whose bulk-to-value ratio is high. Second, while cassava is largely produced for own consumption, the benefits of new technologies in the pipeline depend on growers' capacity to sell larger volumes. A second concern of this research is to address violations of normality and homoskedasticity that can lead to inconsistent estimates in sample selection models as identified by Lahiri and Song (2000).

Using data for cassava farmers in Benin, this paper examines whether growers apply dual-criteria decisionmaking, in which there are distinct decisions of whether to sell cassava and where to sell, or single-criterion decisionmaking, in which the sales location decision is made simultaneously with the market participation decision. This study compares a dual-criteria model with a single-criterion model while correcting for heteroskedasticity and non-normality in the selection equations. In addition, while the literature often focuses on sales quantity (Bellemare and Barrett 2006), this study focuses on production and consumption quantities in order to see whether estimated production and consumption relations differ substantively under the two models. Results support use of the dual-criteria model for the production decision, indicating that high transaction costs affect decisions concerning sales location separately from their effect on decisions to be a seller.

Cassava farmers may make production decisions to maximize utility based on conditions either at the farmgate or at the off-farm location, but not both. When production behavior differs between farmgate and off-farm sellers, adjustments to supply in response to changes in market conditions or in technologies may be more limited than a single-criterion model would suggest.

[1] This paper distinguishes two types of sellers, *on-farm* sellers and *off-farm* sellers. An on-farm seller sells cassava at the farmgate, while an off-farm seller sells cassava at either the market, another home, or the assembly point.

2. SUPPLY RESPONSE FOR SEMI-SUBSISTENCE PRODUCERS

Farmers' self-selection concerning whether to sell crops or not has long been studied. Strauss (1984) lays the groundwork for estimating production and consumption decisions for semisubsistence agricultural households. Goetz (1992) applies the Heckman (1979) sample correction method to analyze how the market supply response is affected by the transaction costs involved with market participation among African farmers. Several studies follow Goetz (1992) to incorporate unobserved transaction costs in estimating marketed supply response by employing the Heckman model (Heltberg and Tarp 2002) or other methods (Key, Sadoulet, and de Janvry 2000; Renkow, Hallstrom, and Karanja 2004; Holloway, Barrett, and Ehui 2005; Bellemare and Barrett 2006).

In contrast to the market participation decision, few studies consider the transaction costs associated with sales location or that producer behavior might vary by chosen sales outlet. Moreover, although systematic distinctions of sales at the farmgate and distant market for commercial crops have been examined (for example, coffee in Uganda, examined by Fafchamps and Hill 2005), few studies analyze whether similar distinctions hold for semisubsistence crops like cassava and how the decision on targeted sales outlet affects production decisions. It is important to analyze whether farmgate sellers respond differently to changes in price and other exogenous conditions than do off-farm sellers. For semisubsistence crops like cassava, sales of which already entail high transaction costs, additional transaction costs in sales location decision may lead farmers to make production and consumption decisions after they decide whether to sell and where to sell. The dual-criteria model posits that there are different sources of fixed costs for each decisionmaking stage and thus two sources of potential sample selection biases.

Models accommodating multiple selection criteria were introduced by Catsiapis and Robinson (1982) and Maddala (1983), and have been applied in several studies of issues other than agricultural supply (Vijverberg 1995). Lahiri and Song (2000) extended a dual-criteria model by using heteroskedastic probit in the selection equations to correct inconsistencies due to heteroskedasticity in selection equations. Dual-criteria models with heteroskedastic selection equations have not been used to analyze the behavior of semisubsistence farmers in Africa. Because the method has not been widely explored in African agricultural contexts, results obtained could be valuable to assess the significance of recognizing self-selection of sales location and the significance of interventions focused on output prices, productivity enhancement, or reduction of the specific transaction costs that drive the decision regarding sales location.

Recent research by Bellemare and Barrett (2006) and Renkow, Hallstrom, and Karanja (2004) has focused on estimation of the fixed transaction costs (FTC) that may drive decisions of whether and where to sell products. While there have been important advances in accounting for unobserved FTC, data limitations prohibit use of many of them in this study. The dataset in this study does not report the transportation costs for all off-farm sellers, as in Bellemare and Barrett (2006) or in Renkow, Hallstrom, and Karanja (2004), and it does not distinguish between fixed and variable costs, as in Bellemare and Barrett (2006). In addition, it seems intractable to combine the dual-criteria structure in this study with methodologies used by Renkow, Hallstrom, and Karanja (2004), who estimated FTCs as a function of explanatory variables simultaneously with supply and demand. Methods applied by Key, Sadoulet, and de Janvry (2000), which allow thresholds for participation to vary across households, and those developed by Holloway, Barrett, and Ehui (2005), which employ a Bayesian econometrics model to obtain robust estimates of the structural equation and a minimum sales quantity threshold at which traders decide to enter the market, also become intractable in the context of a dual-criteria model of extension and other poverty-reduction strategies in rural Ethiopia.

3. CONCEPTUAL FRAMEWORK

The conceptual model developed here posits a semisubsistence farmer who first determines whether to remain autarkic or to engage in markets as a buyer or a seller. This choice defines the farmer's market orientation (denoted *M*) as autarky, buyer, or seller.[2] These categories are exclusive such that a producer must belong to one and only one market orientation. Farmers who select to sell output then make a second decision on sales location (denoted *S*), either selling from the farmgate (on) or selling off-farm (off). An off-farm seller will receive the price minus any per-unit transaction costs (PTC) incurred in bringing the crop to the sales point. The farmer selling from the farmgate will receive the market price minus the PTC of the trader to whom he or she sells.

In a competitive market, once a farmer decides to be a seller, the difference between selling at the market and selling at the farmgate depends only on the difference in farmers' and traders' relative PTC because no fixed costs are incurred for changing the sales location. A single-criterion model can explain behavior when producers change their sales location (*S*) depending on the market conditions within the production period. In an underdeveloped market, however, significantly high fixed transaction costs can arise when switching from selling on-farm to selling off-farm. Some of these costs, described below, are associated with the cost of learning the basic market conditions of each outlet. More important, given their understanding of the high fixed costs incurred by changing the sales outlet, farmers may prefer to choose a targeted sales outlet based on their household characteristics and geographical location, and then make production decisions based on the expected market conditions of that outlet. Farmers' decisions on sales location (*S*) may be irreversible and thus lead to behavior that can be better explained by a dual-criteria model.

In the dual-criteria model, a producer determines his or her market orientation (*M* = autarky, buyer, or seller) at time $t = 0$; sales location (*S* = on or off) is selected at time $t = 1$, and the quantity sold given *M* and *S* (q^{MS}) is chosen at time $t = 2$. It is assumed that the sales location decision is nested within the decision to be a seller, made at $t = 0$, so that the change in relative conditions in different sales outlets does not affect the decision to be a seller. Utility maximization at $t = 2$ can be solved by the usual first-order conditions for $t = 2$ only. Building on Bellemare and Barrett (2006) and Key, Sadoulet, and de Janvry (2000), a household that both produces and consumes cassava has a utility maximization problem in a dual-criteria model as follows:

$$\max_{I_k^M, I_k^S, q_k^{MS}, c_k^{MS}} \quad u(c_k; Z) \tag{1}$$

subject to

$$\sum_{k=1}^{K} \left\{ \left[\left(p_k^m - \tau_{pk}^{off} \right) I_k^{off} + p_k^f I_k^{on} + \left(p_k^m + \tau_{pk}^{buyer} \right) I_k^{buyer} \right] m_k^{MS} + W_2 + T \right\} \geq 0 \tag{2}$$

for all $k = 1, \ldots,$ cassava, $\ldots, K$

$$W_1 = W_0 - \sum_k \sum_M \tau_{fk}^M I_k^M \geq 0 \tag{3}$$

[2] As in Key, Sadoulet, and de Janvry (2000), this study simplifies the analysis by ignoring the possible case in which a cassava farmer becomes both seller and buyer. The seller and buyer in this study are therefore those who only sell and who only buy, respectively.

$$W_2 = W_1 - \sum_k \sum_S \tau_{fk}^S I_k^S \geq 0 \tag{4}$$

$$q_k^{MS} - x_k^{MS} + A_k - m_k^{MS} - c_k^{MS} \geq 0 \tag{5}$$

$$G(q, x; \xi) = 0 \tag{6}$$

$$c_k, q_k, x_k \geq 0, \tag{7}$$

in which I_k^M and I_k^S are discrete variables equal to 1 to identify a producer's market orientation (M) and sales location (S) for good k, such that $I_k^{off} = 1$ for farmers selling off-farm and $I_k^{off} = 0$ for buyers, autarkic growers, and farmers selling from on-farm. Likewise, I^{on} and I^{buyer} designate farmers who sell from on-farm and those that are buyers, respectively. The value of I_k^M is determined at $t = 0$, the value of I_k^S is determined at $t = 1$, and production and consumption of good k given M and S (q_k^{MS} and c_k^{MS} respectively) are both determined at $t = 2$. Although the subscript k is maintained in the subsequent discussion to maintain generality, this study focuses exclusively on cassava. The utility measure $u(c_k; Z)$ is a function of c_k^{MS} and Z (vector of other determinants of utility), maximized at $t = 2$.

Equations (2) through (4) are liquidity constraints. Equation (2) states that at $t = 2$, revenues from all sales and other income transfers must cover expenditures on all purchases. For an off-farm seller of k ($I_k^{off} = 1$), income includes the net supply of each k that is marketed ($m_{k,}$) multiplied by the market sales price (p_k^m), less the per-unit transaction costs that the farmer incurs by taking good k to the off-farm location (τ_p^{off}). For on-farm sellers of k, $I_k^{on} = 1$ and income from k will equal the farmgate price p_k^f times the sales volume m_k. For buyers, the level of m_k will be negative and the unit costs on purchasing will be p_k^m plus the proportional transaction costs of going to market: τ_p^{buyer}. T is exogenous transfers and other incomes. Finally, W_t is unproductive liquid wealth in the beginning of period t. Equation (3) states that in $t = 0$, when the market orientation, M, is determined, the farmer must have enough liquid wealth to cover the fixed costs associated with the specific market orientation, M (τ_f^M), for all goods k, ($\sum_k \sum_M \tau_{fk}^M I_k^M$), and the liquid wealth in the beginning of $t = 1$ (W_1) is the liquid wealth in the beginning of $t = 0$ (W_0) net $\sum_k \sum_M \tau_{fk}^M I_k^M$. Equation (4) sets an analogous constraint on the choice of sales location in period $t = 2$. Resource constraint (5) requires that at $t = 2$, when q_k^{MS} is obtained for given M, S, and each good k, consumption (c_k^{MS}), use of inputs (x_k^{MS}), and sales quantity (m_k^{MS}, negative if purchase quantity) must not be greater than the production (q_k^{MS}) and initial endowment (A_k). The function $G(\cdot)$ in (6) represents the production technology that relates inputs with outputs, with ξ signifying determinants of production other than inputs, x.

The model assumes that the effect of other important exogenous factors at the production decisionmaking stage, such as cassava production risk, are neutral to the relationship between transaction costs, sales locations, and production decisions. In other words, the effect of production risk is not considered in comparing the dual-criteria model with the single-criterion model. This study assumes that, while the production risk is acknowledged, cassava is relatively resistant to various unfavorable agroecological environments, such as drought, and the yield tends to be more stable than the yields of other crops from the farmer's perspective.

The sequential nature of equations (3) and (4) is a key feature of the dual-criteria model. The decision to be a seller at $t = 0$ arises from farmers' needs to turn cassava into a source of income rather than a subsistence food crop. This decision may involve discrete changes in farmers' household economic activities. For example, they may need to start producing other food crops or purchase food commodities to complement the reduction of cassava consumable as food. Farmers may also expect that being a seller, regardless of eventual sales location, will incur the usual transaction costs involved with market participation (including τ_f^S), which may include using the time of a household member; they may therefore start searching for alternative resources, such as labor that can be used to offset the loss of the household member's labor. The transaction costs τ_f^M are those incurred at $t = 0$ in connection with such changes. Although farmers at $t = 0$ do not have exact market information for any outlet, they still decide whether to be a seller or not based on their need to start earning cash through cassava sales or based on other socioeconomic characteristics that may allow them to have a very rough (but not accurate enough to keep from incurring the cost τ_f^S later) idea of the profitability of their potential cassava sales. Farmers decide whether or not to be a seller before incurring τ_f^S because they expect τ_f^S to be high, thus leading to the separation of (3) and (4). Farmers who have committed to incurring τ_f^S and have made plans accordingly will remain cassava sellers and operate other household economic activities in addition to selling cassava.

Once farmers decide to operate as cassava-selling households, they incur τ_f^S to learn the actual market conditions in either farmgate or off-farm outlet. The dual-criteria model assumes that farmers first decide the sales outlet and then incur τ_f^S to find the potential buyers in that outlet and obtain information about important market parameters at the time of sale, such as the expected prices or variability of prices in that sales location, or the transportation cost if it is an off-farm sales location. The τ_f^S also includes the costs of bargaining, screening, or monitoring transactions.

The τ_f^S may be affected specifically by the education level of the household member responsible for cassava marketing because it includes the actual costs of bargaining, screening, or monitoring transactions as well as the costs associated with other key characteristics of cassava markets, such as the proximity of the off-farm market and the number of cassava traders in the area. On the other hand, the determinants for τ_f^M are more general and are likely to involve the characteristics of more household members and the market conditions for many other outputs and inputs. The values of I_k^{M*}, I_k^{S*}, and q_k^{MS*} from (1) are obtained as reduced forms that are functions of the exogenous parameters in (1) through (7). The formulation here can be used to develop empirical models for either a dual-criteria or single-criterion model. Modifying Bellemare and Barrett (2006), a dual-criteria model for cassava production and consumption decisions can be expressed as follows (notation k is dropped):

$$I^{M*} = I(A, W_0, G(\cdot), \tau_f^M) \text{ for all } M \text{ in \{Buyer, Autarky, Seller\} at } t = 0 \tag{8}$$

$$I^{S*} = I(A, W_1, G(\cdot), I^{M*}, \tau_f^S) \text{ for all } S \text{ in \{on, off\} at } t = 1 \tag{9}$$

$$(q^{MS*}, c^{MS*}) = Q(A, W_2, G(\cdot), T, I^{M*}, I^{S*}, p^m, \tau_p^S) \text{ at } t = 2 \tag{10}$$

In contrast, a single-criterion model implies the following:

$$I^{M*} = I(A, W_0, G(\cdot), \tau_f^M) \text{ for all } M \text{ in \{Buyer, Autarky, Seller\}at } t = 0 \tag{11}$$

$$(q^{MS*}, c^{MS*}) = Q(A, W_1, G(\cdot), T, I^{M*}, p^m, \tau_p^S, \tau_f^S) \text{ at } t = 2 \tag{12}$$

The differences between the dual-criteria model and the single-criterion model are that (10) includes I^{S*} but not τ_f^S, while (12) includes τ_f^S but not I^{S*}. Intuitively speaking, a producer facing a larger τ_f^S is unlikely to change his or her sales location, *S*, after allocating inputs for q^{MS*} and planning c^{MS*}, while a producer facing a smaller τ_f^S may benefit from being able to switch between possible sales locations and adjust q^{MS*} and c^{MS*} accordingly, based on the conditions in different outlets observed during the production period. Empirical comparison of (8) thorough (10) with (11) and (12) can determine whether a dual-criteria model better explains the behavior of cassava producers than a single-criterion model.

4. ESTIMATION OF THE MODEL AND ESTIMATION PROCEDURE

This study applies the dual-λ approach suggested by Catsiapis and Robinson (1982) and Maddala (1983) and their extension in Lahiri and Song (2000) because it is free from the assumptions of the independence of irrelevant alternatives (IIE) required in a conditional logit model and it is more informative than a nested logit model (Vijverberg 1995). A heteroskedastic ordered probit is used for the selection equation (8), which assigns buyer = 0, autarky = 1, and seller = 2 as in Bellemare and Barrett (2006), and a heteroskedastic probit is used to estimate (9), in which an on-farm seller = 0 and an off-farm seller = 1. Following Alvarez and Brehm (1998), the heteroskedastic ordered probit is expressed as follows:

$$\begin{aligned}
&\Pr(i = \text{buyer} \mid \psi_i, \pi_i) = \Phi\left[\left(\alpha_1 - \psi_i \gamma\right)/\exp\left(\pi_i \omega\right)\right] \\
&\Pr(i = \text{autarky} \mid \psi_i, \pi_i) = \Phi\left[\left(\alpha_2 - \psi_i \gamma\right)/\exp\left(\pi_i \omega\right)\right] - \Phi\left[\left(\alpha_1 - \psi_i \gamma\right)/\exp\left(\pi_i \omega\right)\right] \\
&\Pr(i = \text{seller} \mid \psi_i, \pi_i) = 1 - \Phi\left[\left(\psi_i \gamma - \alpha_2\right)/\exp\left(\pi_i \omega\right)\right],
\end{aligned} \tag{13}$$

and following Alvarez and Brehm (1995), the heteroskedastic probit is represented by the following:

$$\begin{aligned}
&\Pr(i = \text{on-farm seller} \mid \Psi_i, \Pi_i) = 1 - \Phi\left[\left(\Psi_i \Gamma\right)/\exp\left(\Pi_i \Omega\right)\right] \\
&\Pr(i = \text{off-farm seller} \mid \Psi_i, \Pi_i) = \Phi\left[\left(\Psi_i \Gamma\right)/\exp\left(\Pi_i \Omega\right)\right],
\end{aligned} \tag{14}$$

in which $\Pr(i = \text{buyer} \mid \psi_i, \pi_i)$ is the probability that cassava producer i with ψ_i and π_i becomes a buyer; ψ_i, π_i, Ψ_i, and Π_i represent the explanatory variables; and γ, ω, Γ, and Ω are estimated coefficients. The vectors ψ_i include household size and its square, gender of household head (1 = female), age of household head and squared age, years and squared years of household head education, total value and squared total value of household assets (in U.S. dollars), total farm size (in hectares), distance and squared distance (in meters) to nearest telephone service, distance and squared distance (in kilometers) to nearest passable road, and regional dummies. The vector π_i includes household size, gender, age, dependency ratio,[3] education, assets and squared assets, total farm size, size of storage space inside the house and in the attic (in tons), distance from plot to telephone and to passable road (in meters), membership in a cooperative (yes = 1), and access to credit (yes = 1). The vector Ψ_i includes household size, gender, education, assets, telephone, passable road, distance to paved road (in kilometers), and regional dummies. The vector Π_i includes assets, storage space inside house and attic, distance to telephone, distance to passable road, and distance to paved road. The symbol Φ is the standard normal distribution function, α_1 is the estimated border between buyer and autarky, and α_2 is the estimated border between autarky and seller. Estimates from (13) and (14) are then used to calculate the inverse Mills ratios $\hat{\lambda}_i$ and $\hat{\mu}_i$.[4]

Sales prices for cassava are not considered to be determinants of either market orientation or sales location and thus are not included in ψ_i, or Ψ_i. Due to poor transportation and communications infrastructure in Benin, prices are often difficult to ascertain by smallholder farmers until they become sellers. Several studies either find no significant effect of sales price on participation decisions (Goetz 1992, Heltberg and Tarp 2002, Alene et al. 2008) or do not include the sales price variable in the analysis of decisionmaking at all (Key, Sadoulet, and de Janvry 2000; Fafchamps and Hill 2005; Bellemare and Barrett 2006).

[3] Dependency ratio is measured as the number of household members below 15 and above 59 divided by the number of household members from 15 to 59, inclusive.

[4] $\hat{\lambda}_i = \dfrac{\phi\{-(\psi_i\hat{\gamma} - \hat{\alpha})/\exp(\pi_i\hat{\omega})\}}{\Phi\{-(\psi_i\hat{\gamma} - \hat{\alpha})/\exp(\pi_i\hat{\omega})\}}$ from ordered probit, in which φ is standard normal density function. For an off-farm seller, $\hat{\mu}_i = \dfrac{\phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}{\Phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}$, and for an on-farm seller, $\hat{\mu}_i = -\dfrac{\phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}{1 - \Phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}$.

The use of heteroskedastic ordered probit and heteroskedastic probit in (13) and (14) is important in two ways. First, ignoring the heteroskedasticity in the ordered probit model can make the estimates inconsistent by violating the normality assumption (Lahiri and Song 2000). Second, heteroskedastic (ordered) probit distinguishes differences across farmers regarding how sensitive their decisions on whether and where to sell are to idiosyncratic errors. Such idiosyncratic errors include unexpected shocks that cannot be captured in deterministic ways as other observable characteristics can. Standard ordered probit does not capture differences associated with such idiosyncratic errors. More specifically, a more positive $\pi_{i1}\omega_1$ means the cassava farmer i is less sensitive to idiosyncratic errors in changing market orientation or sales location, as would be expected if the farmer faced higher transaction costs. Similar arguments hold for the choice between seller types in (14). Therefore, including heteroskedastic components is more informative in capturing the structure of unobserved transaction costs that tend to be household-specific.

Once the selection estimates are complete, the supply and consumption of cassava can be estimated using (15) and (16) to operationalize (10). More specifically, if (M, S) = (sell, on) then (15) obtains, while (16) is relevant if (M, S) = (sell, off), where (15) and (16) are

$$\{q^{MS*}, c^{MS*}\} = (p^f, Z, \hat{\lambda}_i, \hat{\mu}_i) \text{ for on-farm sellers and} \tag{15}$$

$$\{q^{MS*}, c^{MS*}\} = (p^m, Z, \tau, \hat{\lambda}_i, \hat{\mu}_i) \text{ for off-farm sellers.} \tag{16}$$

Here Z is a set of exogenous variables that shift production and consumption curves, and τ is a set of variables that affect the producer's proportional transaction costs (PTC), which determine the margin between farmgate and off-farm sales prices. Equations (15) and (16) are estimated separately by using two-stage least squares (2SLS) or Fuller-modified limited-information maximum likelihood (LIML) in case of a weak identification problem (Hahn and Hausman 2003), since income and price are potentially endogenous.

Equations (13) through (16) are based on a premise of dual-criteria decisionmaking. If the single-criterion model is appropriate, then (14) is dropped and (15) and (16) are replaced with

$$\{q^{M*}, c^{M*}\} = (p, Z, \tau, \delta, \hat{\lambda}_i), \tag{17}$$

in which M = sell, $p = p^m$ for those who report off-farm price, $p = p^f$ for those who report on-farm price, and δ is a set of variables that are not included in Z but are expected to affect τ_f^S. These variables include Ψ_i and Π_i in (14) and τ in (16). By construction, equation (17) contains τ not only for off-farm sellers but also for on-farm sellers. Inclusion of τ for on-farm sellers will, however, not affect the estimates by assumption. These two models are compared using a J-test (Davidson and MacKinnon 1981) to see which model better explains production behavior. This non-nested test is used because each model may contain explanatory variables that do not appear in the other model. The inverse Mills ratios $\hat{\mu}_i$ in (15) and (16) do not appear in (17). Likewise, variables δ that are in neither (15) nor (16) appear in (17).

To correct the standard errors in the structural equations given that $\hat{\lambda}_i$ and $\hat{\mu}_i$ are all estimated variables, a bootstrap of the entire estimation procedure is then conducted. Bootstrapping is done with 100 iterations in two steps. First, empirical samples of $\hat{\lambda}_i$ and $\hat{\mu}_i$ are obtained from bootstrap resampling in heteroskedastic ordered probit (13) and probit (14) models. Second, a standard bootstrap is conducted on (15) and (16), except that each run uses different $\hat{\lambda}_i$ and $\hat{\mu}_i$ values obtained from the first step.

5. DATA AND EXPLORATORY ANALYSIS

This paper uses data from a Benin small farmer survey (IFPRI 2004) collected by the International Food Policy Research Institute (IFPRI) and the Laboratoire d'Analyse Regionale et d'Expertise Sociale (LARES). The dataset contains information on the economic activities of 899 Benin agricultural households during the period April 1997 through March 1998. Table 1 summarizes descriptive statistics from the survey. Among the 899 households, 561 report the quantity of cassava harvested. Out of these 561 cassava-producing households, this study drops households that are both sellers and buyers of cassava as in Key, Sadoulet, and de Janvry (2000) and Renkow, Hallstrom, and Karanja (2004). This study therefore uses 543 cassava producers, among which 196 are sellers (127 on-farm sellers and 69 off-farm sellers), 275 are autarkic households, and 72 are buyers.

Table 1. Summary statistics of cassava-producing households

	Total		On-farm seller		Off-farm seller		Autarky		Buyer	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Production (t/year)										
Fresh tuber	5.3	(8.0)	6.5	(8.8)	2.4	(3.1)	0.4	(0.8)	3.5	
Dried tuber	0.6	(0.7)	1.8	(1.6)	0.9	(0.7)	0.5	(0.6)	0.3	(0.2)
Flour	3.6	(7.2)	0.7	(0.5)	4.9	(8.2)	0.1	(0.1)	0.3	
Consumption (t/year)										
Fresh tuber	0.9	(1.5)	1.0	(1.3)	1.0	(2.4)	0.4	(0.8)	3.5	
Dried tuber	0.5	(0.5)	1.0	(0.9)	0.5	(0.3)	0.5	(0.6)	0.3	(0.2)
Flour	0.5	(0.9)	0.2	(0.1)	0.7	(1.1)	0.1	(0.1)	0.3	
Household size	9.1	(5.1)	8.0	(4.3)	8.6	(5.3)	9.6	(5.4)	9.7	(4.8)
Dependency	1.3	(1.0)	1.3	(1.0)	1.1	(0.9)	1.3	(1.0)	1.2	(0.7)
Age	45.9	(13.6)	44.4	(13.9)	46.0	(13.3)	46.0	(13.7)	48.0	(12.9)
Education (years)	1.8	(3.2)	2.9	(3.7)	1.7	(2.9)	1.2	(2.7)	2.2	(4.0)
Literacy (%)	25.1		40.9		27.8		16.6		27.0	
% of female head	4.8		3.8		6.9		4.2		6.8	
Total farm size (ha)	5.2	(5.0)	2.9	(2.8)	3.4	(3.0)	6.7	(5.6)	5.6	(5.4)
Total assets ($1000)	1.0	(2.1)	0.5	(0.7)	0.8	(2.2)	1.2	(2.3)	1.4	(2.8)
Total income ($1000)	1.4	(1.8)	1.5	(2.0)	1.6	(2.3)	1.4	(1.5)	1.2	(1.5)
Storage capacity (t)										
Inside house	1.6	(3.3)	1.3	(2.8)	1.5	(4.2)	1.8	(3.4)	1.3	(2.5)
Attic	2.6	(5.8)	0.9	(2.4)	3.4	(12.6)	3.2	(4.0)	2.3	(4.4)
Warehouse	3.4	(18.8)	0.3	(1.3)	10.2	(43.1)	3.7	(14.5)	1.3	(33.2)
Distance (km) to										
telephone service	19.9	(21.1)	9.7	(8.0)	19.8	(29.2)	25.3	(21.6)	18.0	(18.7)
passable road	5.8	(12.7)	1.8	(2.2)	7.0	(15.5)	6.3	(12.7)	9.9	(18.0)
paved road	24.7	(29.8)	7.3	(7.5)	16.0	(15.4)	31.4	(33.7)	38.5	(33.2)
own farm	3.6	(9.7)	4.6	(18.7)	3.3	(5.6)	3.4	(3.4)	2.7	(3.0)
cassava sales point			26.7	(94.4)						
% of household										
credit access	52.9		77.3		66.7		42.8		35.1	
cooperative membership	59.0		35.6		40.3		70.7		74.3	
own car/truck	1.4		0.0		4.2		1.8		0	
own motorcycle	27.7		34.4		23.6		27.6		20.5	
own bicycle	70.6		58.3		68.1		76.0		74.3	
% of income from cassava sales	16.2	(15.4)	14.1	(12.4)	20.0	(19.5)				
% of income from crop sales	60.3	(32.4)	48.4	(28.3)	61.8	(33.4)	65.3	(32.0)	61.2	(34.7)

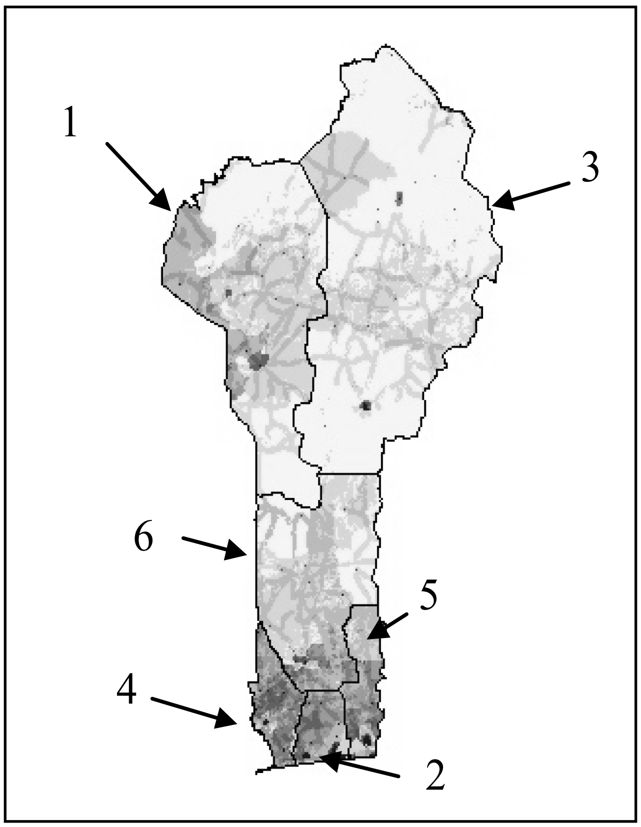
Source: Calculated by authors from IFPRI (2004).

Notes: Age, education, and literacy are of the household head. Numbers in parentheses are standard errors. All dollar amounts are in U.S. dollars.

Estimation of (15) through (17) is based on a sample of 112 on-farm sellers and 59 off-farm sellers. This smaller sample size reflects missing data for some households and removal of sellers who did not report the form of cassava (fresh or dried) as well as households that reported unrealistically large production and consumption quantities given the area planted.

The decision to sell or not is likely to be influenced by place of residence. Figure 1 shows the six administrative regions in Benin as of 1997 and the distribution of population among them. Although some local markets exist in regions one and three, population and consumer markets in Benin are concentrated in regions two, four, and five. Location in regions one, three, and six is thus expected to reduce the likelihood of selling cassava.

Figure 1. Six pre-1999 regions in Benin and their population densities



Source: FAO (2010).
Note: Higher density is indicated by darker color.

Contrasts between the characteristics of on-farm and off-farm sellers support the hypothesis of the dual-criteria model. Most on-farm sellers are closer to more developed infrastructure and mostly sell fresh tubers. Most off-farm cassava sellers, on the other hand, are far from developed infrastructure and sell dried tubers or flour. In close proximity to reliable road infrastructure, traders with vehicles are likely to have lower unit costs than less-capitalized farmers. This cost advantage is likely to be greater for bulkier products (like fresh cassava) and to diminish in areas farther away from roads. Thus the result that more-isolated farmers are less likely to sell on-farm, if they sell, is consistent with the likely differential transaction costs between farmers and traders. Meanwhile, remoteness from a road may not explain whether farmers become sellers or remain autarkic as much as does remoteness from a major market, which is implied by the region in which the farm is found.

Most of the price data used in this study were calculated from reported total value and volume of sales or purchases rather than reflecting a reported unit price. Using calculated unit values rather than prices can introduce simultaneity. With correct use of instrumental variables, however, the regression of quantity on the calculated price produces consistent estimates. Estimation requires data on proportional transaction costs for all producers, but these costs are only observed for those that actually sell off-farm. To capture the PTC that on-farm sellers would face if they sold off-farm, a set of variables for the transaction costs, τ, is identified in (16) by regressing the PTC for each transaction reported by off-farm sellers on a set of potentially related variables as suggested by Vakis, Sadoulet, and de Janvry (2003) and Henning and Henningsen (2007).[5] Results are shown in Table 2. Distance traveled may be endogenous to the PTC since a cassava seller chooses travel distance to maximize profit, which partly depends on PTC. Table 2 presents results from estimations using OLS (ordinary least squares) and 2SLS, instrumenting the distance and squared distance to the sales point. Results from the two approaches are substantively equivalent.

Table 2. Estimated log of transportation costs per sales

	OLS		2SLS	
ln(transportation costs per kg of sales)	**coefficient**	**std.err**	**coefficient**	**std.err**
Potentially endogenous variables				
Distance to sales point (10 km)	.285**	(.054)	.289**	(.055)
Distance to sales point (10 km) squared	-.004**	(.000)	-.004**	(.000)
Exogenous variables				
ln(distance to consumption market [km])	.374**	(.111)	.372**	(.111)
Distance to nearest telephone service (km)	.400	(3.739)	.226	(3.778)
Household head education (years)	-.065	(.041)	-.064	(.041)
Cooperative membership (yes = 1)	-.573	(.312)	-.571	(.312)
λ_{opro}	.404	(.543)	.409	(.543)
λ_{pro}	-.045	(.185)	-.050	(.186)
p-value (overall significance)	.000		.000	
p-value				
H_0: Underidentified			.000	
H_0: Weakly identified			.000	
H_0: Not overidentified			.054	
R^2	.227		.227	
Number of observations	56			

Source: Authors.
Note: Significance level: **1%.

The distance to the sales point has a quadratic and positive effect on the log of PTC. Distance to the consumption market also has a positive effect on the PTC. The proximity to the consumption market may lower the PTC since the consumption market is generally connected by roads in better condition. Based on the results in Table 2, distance to sales point, squared distance to sales point, and ln (distance to consumption market) are included to capture τ in (16) and reflect PTC for all farmers in the sample.

[5] While Vakis, Sadoulet, and de Janvry (2003) use the predicted value of PTC in the production and consumption equations, this paper uses the explanatory variables that significantly affect PTC, but not the predicted PTC itself, due to the complexity in correcting standard errors of equations (8) through (10).

Before estimating the full dual-criteria and single-criterion models, we estimate regressions of production and consumption as functions of sales location and other variables. As results in Table 3 show, the interaction terms for sales location with household head age and with access to credit were significant for production, while the interaction terms with dependency ratio and literacy were significant for consumption. These results suggest that farmers who sell on-farm may differ systematically from those that sell off-farm, and thus the results motivate estimation of the more complex models described in equations (8) to (10) and (11) to (12). The results in Table 3 are meaningful since their indications are robust and partially compensate for the relatively small sample sizes of the dataset used in this study. The results in Table 3 should, however, be regarded only as an indication that the single-criterion model is insufficient in explaining cassava producers' behaviors. The main results discussed in the next section are more definitive and provide clearer policy implications, allowing us to assess whether the high fixed transaction costs associated with the selection of sales location, which prevent cassava farmers from fully benefiting from their access to market, are one of reasons for the insufficiency of the single-criterion model.

Table 3. Potential deviations of off-farm sellers' production and consumption behaviors from on-farm sellers' (simple OLS)

Dependent variable	**ln(harvest [kg])**		**ln(consumption [kg])**	
	Coefficient	**Std.err**	**Coefficient**	**Std.err**
ln(price)	-.091	(.151)	.028	(.203)
Total income ($1000)	.122**	(.036)	.193**	(.046)
Gender	-.034	(.296)	.125	(.400)
Household head age	.004	(.006)	-.010	(.008)
Household size	.003	(.018)	.063**	(.022)
Dependency	.052	(.080)	-.263*	(.108)
Total assets ($1000)	.020	(.053)		
Literacy (yes = 1)	.644**	(.169)	-.032	(.226)
Cooperative membership (yes = 1)	-.164	(.139)	-.251	(.188)
Access to credit	-.273	(.220)		
Total farm size (ha)	.130**	(.026)		
Distance to telephone (km)	.016**	(.006)		
Distance to plots (km)	.004	(.004)	-.003	(.005)
ln(consumption market [km])	-.050	(.081)	-.055	(.105)
Total storage space (1000 t)	-.001	(.002)	-.002	(.003)
Gift			.769**	(.184)
Distance to sales point (10 km)	.008	(.012)	.032*	(.014)
Region one	-.158	(.693)	-.087	(.866)
Region two	1.707**	(.203)	1.175**	(.269)
Region three	-.805	(.828)	.032	(1.092)
Region four	.209	(.276)	.333	(.380)
Region six	1.252**	(.436)	1.246*	(.499)
Flour	-1.180**	(.350)	-.954*	(.460)
Dried tuber	-.548	(.526)	.192	(.695)

Table 3. Continued

Dependent variable	ln(harvest [kg])		ln(consumption [kg])	
	Coefficient	**Std.err**	**Coefficient**	**Std.err**
Off-farm status (yes = 1)	1.484	(1.125)	-.090	(1.467)
Off-farm status * ln(price)	-.356	(.220)	-.331	(.294)
Off-farm status * Household head age	-.018†	(.011)	.003	(.015)
Off-farm status * Dependency	.142	(.177)	.722**	(.236)
Off-farm status * Literacy (yes = 1)	-.509	(.311)	.729†	(.400)
Off-farm status * Access to credit	.878*	(.366)		
Constant	8.133**	(.814)	6.975**	(.958)
p-value of overall fit	.000		.000	
No. of observations	165		165	

Source: Authors.

Note: Independent variables are selected from those in the single-criterion model (Table 8) for production and consumption. Because interacting all variables with off-farm seller status would overburden the relatively small sample size, all squared terms are excluded. Significant determinants of off-farm seller status shown in Table 5 (household head education, distance to paved road, and distance to passable road) are also excluded to avoid the endogeneity of many variables interacted with off-farm seller status. Regional dummies as well as forms of cassava (flour or dried tuber as opposed to fresh tuber) are not interacted with off-farm seller status. Finally, to present the results in a parsimonious way, many less-significant interactive terms are dropped. Excluding those insignificant interactive terms does not affect the qualitative results indicating systematic variations between the behavior of on-farm sellers and off-farm sellers.

Significance levels: **1%, *5%, †10%.

6. RESULTS

The primary goal of this paper is to empirically determine, based on results of a J-test, whether the dual-criteria model explains cassava producers' behavior better than the single-criterion model. This section briefly interprets the results of each model and then discusses the test results and their policy implications.

6.1. Estimation of Market Orientation and Sales Location

The heteroskedastic ordered probit estimation (13) includes household characteristics and factors that affect access to market (Table 4). In Table 4, the set of coefficients γ and ω in (13) are shown in the third and fifth data columns respectively. Similarly, in Table 5, the set of coefficients Γ and Ω in (14) are shown in the third and fifth data columns respectively. Squared terms are included to capture the complicated structure of unobserved transaction costs that affect a cassava producer's decision to participate in the market. There are fewer variables in the probit estimation of sales location than in the estimation of market participation since the differences among cassava sellers are less pronounced than those among all cassava producers (Table 5). The distance to a paved road is added since proximity to paved roads is expected to reduce the PTC of traders and increase the opportunity for sellers to find a buyer at the farmgate. The test statistics (p-value) in Tables 4 and 5 indicate the presence of heteroskedasticity in the standard (ordered) probit model. Heteroskedastic models exhibit less violation of the normality assumption, which justifies the use of heteroskedastic ordered probit and heteroskedastic probit.[6] In addition, certain insignificant variables are dropped from each specification when the omission of such variables leads to stronger evidence of consistency of the model, which is diagnosed by the normality test and homoskedasticity test.

The market participation decision by cassava producers seems to be influenced by the region of residence through unobserved socioeconomic or environmental characteristics. Regions one, three, and six are more remote from the larger consumption markets for cassava, so it is intuitive that producers in those regions are less likely to sell at all than producers elsewhere (Figure 1). At the time of the survey, greater distance to a mainline telephone service increased the likelihood that a cassava farmer would be a seller.[7] Since telephone service was restricted to developed areas, farmers closer to mainline telephones were likely to have opportunities to sell higher-value, perishable commodities rather than cassava or to take on non-farm employment. Cassava farmers with higher education seem less sensitive to idiosyncratic errors in changing their market orientation regime, with higher opportunity costs of searching for buyers or sellers, or searching for an alternative source of cassava (if already a buyer) or income (if already a seller). Based on Table 5, a seller closer to a paved road is more likely to be an on-farm seller, possibly due to a higher chance of having buyers with vehicles traveling to the farm. A producer located farther from a passable road who decided to be a seller is more sensitive to idiosyncratic errors in deciding between selling on-farm and off-farm, although in the dual-criteria model such a decision is made only before (not after) production and consumption decisions are made.

[6] Both heteroskedasticity and normality are tested using the Lagrange multiplier (LM) test. The test for normality is derived from those in Bera, Jarque, and Lee (1984) and Glewwe (1997), as discussed in Appendix A.

[7] This holds if the telephone service is more than approximately 100 meters away (= .021 / .00034 * 2), which is the case for most cassava farmers.

Table 4. Ordered probit results

	Homoskedastic ordered probit		Heteroskedastic ordered probit			
					Heteroskedasticity specification	
	Coefficient gamma (γ)	Std.err	Coefficient gamma (γ)	Std.err	Coefficient omega (ω)	Std.err
Household size	-.018	(.031)	-.036	(.040)	-.014	(.019)
Household size squared	.001	(.001)	.001	(.002)		
Gender of hhd head (female=1)	-.150	(.260)	-.158	(.254)	-.051	(.341)
Age of household head	-.001	(.024)	-.006	(.027)	.004	(.005)
Age squared	.000	(.000)	.000	(.000)		
Dependency ratio					-.001	(.070)
Household head education (years)	.015	(.042)	.025	(.054)	.046*	(.023)
Education squared	-.005	(.004)	-.003	(.006)		
Total assets ($)	-.002	(.107)	-.070	(.122)	-.131	(.143)
Total assets squared	.000	(.000)	.000	(.000)	.000	(.000)
Total farm size (1000 ha)	.003	(.002)	.010	(.009)	.003	(.003)
Storage inside house (1000 t)					-.014	(.018)
Storage in attic (1000 t)					.008	(.010)
Distance to telephone (m)	-.021*	(.008)	-.021*	(.010)	-.007	(.004)
Squared distance to telephone (10 m)	.039**	(.010)	.034**	(.012)		
Distance to passable road (km)	-.013	(.015)	-.016	(.018)	.003	(.007)
Squared distance (passable road)	.000	(.000)	.000	(.000)		
Distance to plot (km)					-.224	(.209)
Cooperative membership (yes=1)					.079	(.139)
Access to credit (yes = 1)					-.053	(.126)
Region one	-1.973**	(.230)	-1.450**	(.396)		
Region two	.870**	(.239)	.932**	(.348)		
Region three	-1.809**	(.200)	-1.300**	(.364)		
Region four	-.742**	(.204)	-.268	(.205)		
Region six	-1.540**	(.197)	-1.056**	(.326)		
a_1	-2.795**	(.607)	-2.461**	(.822)		
a_2	4.916**	(.111)	4.252**	(.500)		
Log-likelihood	-386.017		-352.722			
p-value (overall significance)	.000		.000			
p-value (homoskedasticity)	.001					
p-value (normality)			.026			
No. of observations	543		543			

Source: Authors.
Note: Buyer = 0, Autarky = 1, Seller = 2. Significance levels: **1%, *5%.

Table 5. Probit results

	Homoskedastic probit		Heteroskedastic probit		Heteroskedasticity specification	
	Coefficient GAMMA (Γ)	Std.err	Coefficient GAMMA (Γ)	Std.err	Coefficient OMEGA (Ω)	Std.err
Household size	.022	(.023)	.010	(.012)		
Gender of hhd head (female=1)	.652	(.438)	.207	(.182)		
Household head education (years)	-.077*	(.035)	-.068	(.049)		
Total assets ($)	-.023	(.108)	-.034	(.047)	.166	(.175)
Storage inside house (1000 t)					-.071	(.061)
Storage in attic (1000 t)					.009	(.024)
Distance to telephone (m)	-.017	(.015)	-.016	(.015)	-.002	(.054)
Distance to passable road (km)	.033	(.029)	.018	(.016)	-.259*	(.113)
Distance to paved road (km)	.056**	(.013)	.033*	(.014)	-.026	(.042)
Region one	1.097	(.578)	1.112	(.656)		
Region two	-.328	(.244)	-.157	(.108)		
Region three	-.980	(.981)	-.399	(.330)		
Region six	.099	(.322)	-.204	(.205)		
Constant	-.854**	(.283)	-.378*	(.187)		
Log-likelihood	-104.530		-97.701			
p-value (overall significance)	.000		.000			
p-value (homoskedasticity)	.000					
p-value (normality)			.998			
No. of observations	196		196			

Source: Authors.
Note: On-farm seller = 0, off-farm seller = 1. Significance levels: **1%, *5%.

6.2. Production and Consumption Decisions

Tables 6 through 8 present the results of cassava production and consumption equations (15) through (17). Price and income are assumed to be endogenous because price is calculated using sales quantity and income includes cassava sales. The 2SLS and Fuller-modified LIML estimates are therefore used.[8] Discussion of results is primarily concerned with comparing overall capacity of the two models to explain cassava producers' behavior but also highlights differences in the implications of the results across the models.

Cassava production by on-farm sellers is positively affected by total farm size but unaffected by total income (Table 6). Conversely, cassava production by off-farm sellers is unaffected by total farm size, possibly reflecting constraints in marketing capacity, but positively affected by income. The income relationship suggests that more financial resources can facilitate transporting cassava to diverse sales locations. Estimated price elasticities of supply are statistically insignificant under both models.

Home consumption of cassava for on-farm sellers is positively affected by household size and total assets (Table 7). Home consumption of cassava for off-farm sellers is affected by dependency and total income. Household size may not affect cassava consumption for off-farm sellers if cassava is only one of many staple foods in the region (maize and rice being alternatives).

Estimations in Tables 6 through 8 control for several factors. Dummy variables are used for households reporting the quantity of cassava in flour or dried tubers instead of fresh tubers.[9] Another dummy variable, gift, is included for households that use cassava as gifts or substitutes for cash payments; this is a common practice for some households and reflects an exogenous social structure that affects cassava demand for particular households.

The single-criterion model in Table 8 includes variables that appear in the production equation for at least one type of seller in Table 6, but also some additional variables, namely storage area available in the house or attic and distance to a passable road or a paved road in the consumption estimation, which are used to represent τ_f^S (fixed transaction costs for choosing sales location) in equation (12) of the single-criterion model. Most of those additional variables are found to significantly affect cassava sellers' decisions on sales location in equation (14).

Most of the signs of significant variables are consistent with economic theory. The negative coefficient on cooperative membership may reflect cooperatives that facilitate production of more-commercial crops rather than cassava. Most other variables do not significantly affect the production or consumption of cassava.

[8] Consistent estimation under 2SLS requires that the model satisfy the orthogonality conditions as well as certain conditions for the identification of the model. Structural and instrumental variables are occasionally included or excluded arbitrarily in a manner that minimizes the risk of inconsistency and omitted-variable biases, given the constraints of the small sample size. Appendix B discusses issues regarding diagnostic tests for consistency of both 2SLS and Fuller-modified LIML as well as the choice between the two. In addition, production and consumption equations are estimated separately instead of jointly, since a joint estimation can transmit the effect of potential misspecifications of one model to the other even though there may be some gains in efficiency of the estimates.

[9] Almost all households in the dataset reported the quantity in only one of the three forms; very few reported the quantity in more than one form. The latter households are excluded from the regression.

Table 6. Cassava production with sellers separated

Dependent variable	On-farm sellers (LIML)			Off-farm sellers		
ln(harvest [kg])	**Coefficient**	**Std.err**	**Bootstrap std.err**	**Coefficient**	**Std.err**	**Bootstrap std.err**
ln(price)	.448	(1.119)	(2.364)	.032	(.434)	(.353)
Household size	-.043	(.029)	(.081)	.025	(.032)	(.030)
Dependency	.020	(.101)	(.187)	.162	(.179)	(.156)
Total income ($1000)	.310	(.312)	(.723)	.315**	(.145)	(.065)
Total assets ($1000)	.785	(1.207)	(2.348)			
Total farm size (ha)	.155*	(.044)	(.071)	.064	(.075)	(.051)
Household head age	-.007	(.006)	(.014)			
Gender	-.042	(.766)	(1.138)	-.638	(.490)	(.447)
Education (years)	-.041	(.260)	(.426)			
Education squared	.016	(.026)	(.050)			
Literacy (yes = 1)	.147	(.356)	(.587)			
Cooperative membership (yes = 1)	.116	(.316)	(.560)	-.262	(.352)	(.293)
Distance to telephone (km)	.023	(.015)	(.043)			
Distance to passable road (km)	-.084	(.077)	(.109)			
Distance to paved road (km)	-.002	(.026)	(.052)			
Own motorcycle	-.597	(.387)	(.541)	-.341	(.381)	(.284)
Own bicycle	.281	(.277)	(.618)	-.299	(.294)	(.249)
Access to credit	-.155	(.329)	(.478)			
λ_{opro}	10.996*	(10.579)	(5.193)	-11.440**	(4.991)	(2.336)
λ_{pro}	-.640	(1.028)	(1.475)	.041	(.378)	(.356)
ln(consumption market [km])				-.190	(.195)	(.158)
Distance to sales point (10 km)				.070	(.072)	(.069)
Distance squared (sales point)				-.001	(.001)	(.001)
Region one	7.209	(4.151)	(8.544)	-.837	(1.196)	(.964)
Region two	2.346	(.580)	(1.781)	-1.047	(1.067)	(.798)
Region three	.061	(2.346)	(6.286)			
Region four	1.283	(.642)	(1.319)	-2.067**	(1.035)	(.769)
Region six				-.151	(1.037)	(.741)
Flour	-2.917	(2.310)	(5.094)	.213	(.715)	(.514)
Dried tuber	-1.236	(.958)	(2.032)	.556	(.900)	(.739)
Constant	4.142	(3.633)	(9.112)	7.568**	(1.628)	(1.508)

Table 6. Continued

Dependent variable	On-farm sellers (LIML)			Off-farm sellers		
ln(harvest [kg])	**Coefficient**	**Std.err**	**Bootstrap std.err**	**Coefficient**	**Std.err**	**Bootstrap std.err**
p-value						
H_0: overall insignificance	.000			.000		
H_0: not overidentified	.458			.108		
H_0: underidentified	.001			.005		
H_0: weakly identified						
ln(price)	.018			.041		
Total income	.011			.014		
No. of observations	112			59		

Source: Authors.
Note: Significance levels: **1%, *5%.

Table 7. Cassava consumption with sellers separated

Dependent variable	On-farm sellers			Off-farm sellers		
ln(harvest [kg])	**Coefficient**	**Std.err**	**Bootstrap std.err**	**Coefficient**	**Std.err**	**Bootstrap std.err**
ln(price)	-.909	(.619)	(.665)	-.423	(.328)	(.347)
Household size	.072*	(.038)	(.033)	.039	(.032)	(.029)
Dependency	-.199	(.125)	(.121)	.494*	(.195)	(.200)
Total income ($1000)	-.163	(.152)	(.174)	.323**	(.095)	(.065)
Total assets ($1000)	1.606*	(.672)	(.683)			
Household head age	-.004	(.010)	(.009)			
Gender	.453	(.753)	(.697)			
Education (years)	.019	(.050)	(.047)			
Distance to plots (km)				.008	(.074)	(.074)
Distance to plots squared				.000	(.002)	(.002)
Cooperative membership (yes = 1)				.151	(.330)	(.332)
λ_{opro}	-22.926**	(12.016)	(3.404)	-7.968**	(3.193)	(1.987)
λ_{pro}	.170	(.545)	(.456)	.445	(.354)	(.349)
ln(consumption market [km])				.087	(.167)	(.176)
Distance to sales point (10 km)				-.023	(.100)	(.088)
Distance to sales point squared				.001	(.001)	(.001)
Region one	.020	(4.946)	(4.807)			
Region two	.488	(.530)	(.614)			
Region three	.302	(1.706)	(1.896)			
Region four	.622	(.642)	(.595)			

Table 7. Continued

Dependent variable	On-farm sellers			Off-farm sellers		
ln(harvest [kg])	**Coefficient**	**Std.err**	**Bootstrap std.err**	**Coefficient**	**Std.err**	**Bootstrap std.err**
Flour	-.235	(1.434)	(1.535)	.332	(.483)	(.500)
Dried tuber	-.380	(1.437)	(1.442)	1.325*	(.520)	(.614)
Gift	.729*	(.264)	(.280)	.796*	(.279)	(.297)
Constant	8.257**	(2.152)	(2.652)	5.050*	(1.470)	(1.589)
p-value						
H_0: overall insignificance	.000			.000		
H_0: not overidentified	.627			.054		
H_0: underidentified	.003			.004		
H_0: weakly identified						
ln(price)	.001			.025		
Total income	.002			.018		
No. of observations	112			59		

Source: Authors.
Note: Significance levels: **1%, *5%.

Table 8. Cassava production and consumption in single-criterion model

Dependent variable	Production (LIML)			Consumption (LIML)		
ln(harvest [kg])	**Coefficient**	**Std.err**	**Bootstrap std.err**	**Coefficient**	**Std.err**	**Bootstrap std.err**
ln(price)	.160	(.659)	(1.185)	-1.571	(.907)	(1.931)
Household size	.048	(.031)	(.044)	.112*	(.040)	(.052)
Dependency	-.045	(.248)	(.274)	-.172	(.155)	(.197)
Total income ($1000)	-.446	(.245)	(.405)	-.496	(.231)	(.407)
Total assets ($1000)	1.148*	(.445)	(.528)	.996*	(.357)	(.416)
Total assets squared	-.049	(.019)	(.234)	-.044*	(.021)	(.022)
Household head age	.024	(.048)	(.076)	-.019	(.011)	(.013)
Gender	-.116	(.474)	(.658)	.532	(.614)	(.728)
Education (years)	.058	(.148)	(.218)	.017	(.049)	(.046)
Education squared	-.012	(.015)	(.021)			
Distance to plots (km)	.017	(.024)	(.035)	.017	(.031)	(.048)
Distance to plots squared	.000	(.000)	(.000)	.000	(.000)	(.000)
Total farm size (ha)	.210**	(.051)	(.052)			
Cooperative membership (yes = 1)	-.776*	(.303)	(.358)	-.510	(.316)	(.336)
Access to credit	.097	(.266)	(.264)			

Table 8. Continued

Dependent variable	Production (LIML)			Consumption (LIML)		
ln(harvest [kg])	**Coefficient**	**Std.err**	**Bootstrap std.err**	**Coefficient**	**Std.err**	**Bootstrap std.err**
Distance to telephone (km)	.003	(.016)	(.017)			
Distance to passable road (km)	.047	(.035)	(.033)	.020	(.029)	(.030)
Distance to paved road (km)	.022	(.014)	(.015)	-.007	(.018)	(.022)
Own car/truck	-3.728	(2.289)	(2.561)			
Own motorcycle	-.341	(.284)	(.308)			
Own bicycle	-.423	(.264)	(.372)			
λ_{opro}	26.677**	(12.163)	(4.908)	9.562*	(11.138)	(4.461)
Storage inside house (1000 t)	-.034	(.029)	(.044)	.043	(.038)	(.039)
Storage in attic (1000 t)	-.025	(.028)	(.054)	.041	(.036)	(.058)
ln(consumption market [km])	.021	(.135)	(.138)	-.159	(.165)	(.180)
Distance to sales point (10 km)	-.006	(.111)	(.138)	-.081	(.132)	(.147)
Distance to sales point squared	.000	(.014)	(.017)	.001	(.002)	(.002)
Region one	-3.482	(1.697)	(1.881)	-3.230	(1.770)	(2.271)
Region two	2.255*	(.547)	(.758)	.567	(.686)	(1.269)
Region three	-2.340	(1.850)	(1.886)	-3.331	(2.420)	(3.633)
Region four	-.217	(.493)	(.659)	-.726	(.667)	(1.013)
Region six	-.470	(.929)	(.751)	-.457	(1.150)	(1.077)
Flour	-1.783	(1.368)	(2.392)	2.250	(1.881)	(3.895)
Dried tuber	-.675	(.993)	(1.484)	1.855	(1.390)	(2.182)
Gift				.633*	(.277)	(.281)
Constant	5.427	(3.225)	(4.946)	11.491	(3.573)	(7.200)
p-value						
H_0: overall insignificance	.000			.000		
H_0: not overidentified	.557			.566		
H_0: underidentified	.001			.002		
H_0: weakly identified						
ln(price)	.242			.315		
Total income	.319			.062		
No. of observations	165			165		

Source: Authors.
Note: Significance levels: **1%, *5%.

6.3. Comparison of Dual-Criteria and Single-Criterion Decisionmaking Models Using a *J-test*

The combined estimation results suggest that both dual-criteria and single-criterion models provide logical explanations of cassava producer behavior, but they have different explanatory power. Table 9 summarizes the results of the J-test that compares the explanatory power of the dual-criteria and single-criterion models. A high p-value indicates that one model is at least as good as the other model. For example, the p-value of .371 for the production of on-farm sellers in the dual-criteria model indicates that the dual-criteria model is at least as good as the single-criterion model in explaining the production behavior of on-farm sellers. In contrast, the p-value of .002 for production in the single-criterion model indicates that the single-criterion model is not as good at explaining cassava production behavior as the dual-criteria model. Overall, the J-test implies that the dual-criteria model provides information regarding cassava production behavior that is not available in the single-criterion model. The single-criterion model alone, however, may be able to fully explain cassava consumption behaviors. The J-test supports the decisionmaking structure of equations (8) through (10) over that of equations (11) and (12).

Table 9. p-value from J-test by Davidson and MacKinnon (1981)

	Separate			**Pooled**
	On-farm seller	**Off-farm seller**	**Joint ($\chi^2[2]$)**	
Production	.371	.189	.286	.002
Consumption	.220	.004	.009	.496
Joint ($\chi^2[4]$)			.017	.007

Source: Authors.
Note: p-value of .371 means that the pooled estimation of production does not add any explanatory power to the estimation of production for on-farm sellers.

Cassava farmers in Benin face high transaction costs that affect not only their market participation decisions but also their choice of sales locations. Results support the notion that transaction costs lead cassava-selling farmers to make production decisions based on an intended sales outlet. Once production decisions are made, it appears that farmers cannot easily alter them. As a result, their ability to benefit from market participation is limited because they cannot adjust production or market outlet after learning of conditions in markets other than the one they initially chose.

The key empirical value of the dual-criteria model in its current form is that it provides consistent estimates in the face of cassava sellers' sequential self-selections at two stages. While the development of this model is the primary contribution of this paper, its small-sample property will need to be assessed in future studies. One concern in the empirical estimation of the dual-criteria model in this study is that there are only 59 off-farm sellers that can be used in our dataset. Although the estimates are still consistent, their precision is compromised because small sample size can lead to a lower efficiency, weak identification, and multicollinearity. The specific results therefore need to be interpreted with caution.

7. CONCLUSION

This study examines whether cassava growers in Benin decide whether and where to sell their produce before deciding on target production and consumption levels. Such behavior could be explained by high transaction costs associated with sales locations. The literature suggests that semisubsistence farmers often make market participation decisions before they make production and consumption decisions. If cassava sellers also decide the sales location before making production and consumption decisions, they are further constrained by high transaction costs and their potential to benefit from markets is further limited. Such behavior would also suggest a value to addressing the specific transaction costs that lead to rigid decisions on sales location.

Results indicate that cassava producers may first decide whether and where to sell cassava and then allocate the production resources, rather than deciding the sales location simultaneously with production levels. A cassava producer may decide where to sell cassava before knowing the market conditions at different outlets because of the high fixed costs involved in finding buyers or in discovering prices and price risks in each outlet.

Overall, the results suggest that the policies in African countries to stimulate growth of semisubsistence farmers’ income through increased access to markets should be combined with efforts to lower the fixed transaction costs associated with not only their market participation decisions but also their sales location decisions. As a methodological contribution, the findings also indicate that the estimation may still be inconsistent even if sample selection bias is corrected using a dual-criteria decisionmaking model, as in this study, if the heteroskedasticity and normality of the selection equations are ignored, which has been rather common practice in the literature.

APPENDIX A. NORMALITY TEST OF HETEROSKEDASTIC ORDERED PROBIT AND HETEROSKEDASTIC PROBIT

The normality test for the heteroskedastic ordered probit model is extended from Glewwe (1997). Following Glewwe (1997), the Lagrange multiplier (LM) test statistics for a normality test of a heteroskedastic ordered probit model are

$$LM = \begin{pmatrix} J1 \\ J2 \end{pmatrix}'$$

$$\left(\begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} - \left(\begin{bmatrix} J'_{\gamma+1} & J'_{\omega+1} & J'_{\alpha k+1} \\ J'_{\gamma+2} & J'_{\omega+1} & J'_{\alpha k+2} \end{bmatrix} \begin{bmatrix} J_{\gamma\gamma} & J_{\gamma\omega} & J_{\gamma\alpha} \\ J_{\omega\gamma} & J_{\omega\omega} & J_{\omega\alpha} \\ J_{\alpha\gamma} & J_{\alpha\omega} & J_{\alpha\alpha} \end{bmatrix}^{-1} \begin{bmatrix} J_{\gamma+1} & J_{\gamma+2} \\ J_{\omega+1} & J_{\omega+2} \\ J_{\alpha k+1} & J_{\alpha k+2} \end{bmatrix} \right)^{-1} \right) \begin{pmatrix} J1 \\ J2 \end{pmatrix}$$

$$\sim \chi^2(2)$$

in which the notations are the same as in Glewwe (1997), except the following: β and γ in Glewwe (1997) are replaced with γ and ω to be consistent with (13), and k is disaggregated into γ and ω except J_{ak+1} and J_{ak+2}.

Let us also define

$$Z_0 = \frac{\alpha_j - \psi_i'\gamma}{\exp(\pi_i \omega)}, \; Z_{-1} = \frac{\alpha_{j-1} - \psi_i'\gamma}{\exp(\pi_i \omega)}.$$

When $G_{\beta_{ij}}$ and $G_{\gamma_{ij}}$ are replaced with $G_{\gamma_{ij}}$ and $G_{\omega_{ij}}$, we then have the following:

$$G_{\gamma_{ij}} = \frac{\phi(Z_{-1}) - \phi(Z_0)}{\Phi(Z_0) - \Phi(Z_{-1})} \cdot \frac{1}{\exp(\pi_i \omega)}$$

$$G_{\alpha_{ij}} = \frac{\phi(Z_0)}{\exp(\pi_i \omega)[\Phi(Z_{-1}) - \Phi(Z_0)]}, \; G^{+}_{\alpha_{ij}} = \frac{\phi(Z_0)}{\exp(\pi_i \omega)[\Phi(Z_0) - \Phi(Z_{+1})]}$$

$$G_{c1ij} = \frac{\left[(Z_{-1})^2 - 1\right]\phi(Z_{-1}) - \left[(Z_0)^2 - 1\right]\phi(Z_0)}{\Phi(Z_0) - \Phi(Z_{-1})}$$

$$G_{c2ij} = \frac{(Z_{-1})\left[3 + (Z_{-1})^2\right]\phi(Z_{-1}) - (Z_0)\left[3 + (Z_0)^2\right]\phi(Z_0)}{\Phi(Z_0) - \Phi(Z_{-1})}.$$

And additional components are

$$G_{\omega_{ij}} = \frac{(\alpha_{j-1} - \psi_i'\gamma)\phi(Z_{-1}) - (\alpha_j - \psi_i'\gamma)}{\exp(\pi_i \omega)[\Phi(Z_0) - \Phi(Z_{-1})]}$$

$$J_{\gamma\omega} = \sum_{i=1}^{N} \psi_i \pi_i' \sum_{j=0}^{Y} G_{\omega_{ij}} G_{\beta_{ij}} E\left[I_{ij} \mid \psi_i\right] = \sum_{i=1}^{N} \psi_i \pi_i' \sum_{j=0}^{Y} G_{\omega_{ij}} G_{\beta_{ij}} \left[\Phi(Z_{0i}) - \Phi(Z_{-1i})\right]$$

$$J_{\omega\omega} = \sum_{i=1}^{N} \pi_i \pi_i' \sum_{j=0}^{Y} \left(G_{\omega_{ij}}\right)^2 E\left[I_{ij} \mid \psi_i\right] = \sum_{i=1}^{N} \pi_i \pi_i' \sum_{j=0}^{Y} \left(G_{\omega_{ij}}\right)^2 \left[\Phi(Z_{0i}) - \Phi(Z_{-1i})\right]$$

$$J_{\alpha\omega} = \sum_{i=1}^{N} \psi_i \left[G_{\omega_{ij}} G_{\alpha_{ij}} \left[\Phi(Z_{0i}) - \Phi(Z_{-1i})\right] - G_{\omega_{ij+1}} G^{+}_{\alpha_{ij+1}} \left[\Phi(Z_{1i}) - \Phi(Z_{0i})\right] \right].$$

The normality test for heteroskedastic probit modifies the test for standard probit by Bera, Jarque, and Lee (1984). LM test statistics are very similar to the expression in Bera, Jarque, and Lee (1984, 571), except for the following modification:

$$X(i) = \begin{bmatrix} \dfrac{\psi_i'}{\exp(\pi_i \omega)} \\ \dfrac{\pi_i (\psi_i' \gamma)}{\exp(\pi_i \omega)} \\ \left(\dfrac{\psi_i' \gamma}{\exp(\pi_i \omega)}\right)^2 - 1 \\ \left(\dfrac{\psi_i' \gamma}{\exp(\pi_i \omega)}\right)\left(3 + \left(\dfrac{\psi_i' \gamma}{\exp(\pi_i \omega)}\right)^2\right) \end{bmatrix}.$$

In addition, all instances of $x_i'\beta$ in the expression are replaced with $\left(\dfrac{\psi' \gamma_i}{\exp(\pi_i \omega)}\right)$.

APPENDIX B. IDENTIFICATION TESTS IN 2SLS AND CHOICE BETWEEN 2SLS AND FULLER-MODIFIED LIML

The following identification tests are conducted: 1) Sargan's test for overidentification, 2) underidentification tests, 3) weak identification tests using Shea's partial R2. In two-stage least squares, overidentification leads to inconsistent estimates, while underidentification and weak identification lead to asymptotic results that are less reliable than identification is proper (Staiger and Stock 1997). To test for weak identification, Shea's partial R2 (Shea 1997) is used instead of the test suggested by Stock and Yogo (2002) since partial R2 is less susceptible to the estimated variance–covariance matrix than the latter test, which relies more on variance–covariance matrix.

Hahn and Hausman (2003) suggest the use of Fuller-modified LIML instead of 2SLS if the weak identification problem is persistent, since the former performs better in the presence of a weak identification problem. In this study, the parameter α in Fuller-modified LIML is set to a value of one because it provides the nearly unbiased estimator (Fuller 1977).

Appearing at the bottoms of Tables 6 through 8 are the p-values based on the test statistics mentioned above for overidentification, underidentification, and weak identification. All models presented reject overidentification, underidentification, and weak identification at five percent significance levels. (Due to the nature of the tests and null hypotheses tested, p-values should be above five percent for the overidentification and weak identification tests but below five percent for the underidentification test. This is because the null hypothesis for the underidentification test is that the model is underidentified, which must be rejected.)

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